

Machinery fault diagnosis and signal processing
Prof. A. R. Mohanty
Department of Civil Engineering
Indian Institute of Technology – Kharagpur

Module No # 07
Lecture No # 34
Fault Detection in Motors And Transformers

So far we have discussed about using (()) (0:21) monitoring as a tool for finding out the health condition of machines and then we saw wear debris analysis and all contaminants analysis could be used to pin point the fault in machines. Now in this class and so on we will be discussing about the other techniques of condition monitoring which constitute towards the ten percent of the monitoring methods throughout the industry in the world.

Especially motor current signature analysis has come up as a very emerging technology in condition based maintenance and we at IIT Kharagpur have contributed a lot to it through our research over the last decade and in fact in this class and subsequent class I will be also presenting some results from our research. We had at IIT Kharagpur and before I discuss on motor current signature analysis.

I would like to in this class talk about, how do you find out the defects in electrical motors as you know 90 % of cases in systems in machines. The driving is on the electrical motor, so fault in an electrical motor is of paramount importance. So it has to be detected beforehand, so that we do not have an unnecessary downtime along with motors. I will be discussing about transformers as well.

(Refer Slide Time: 01:57)

Classification of Electric Machines

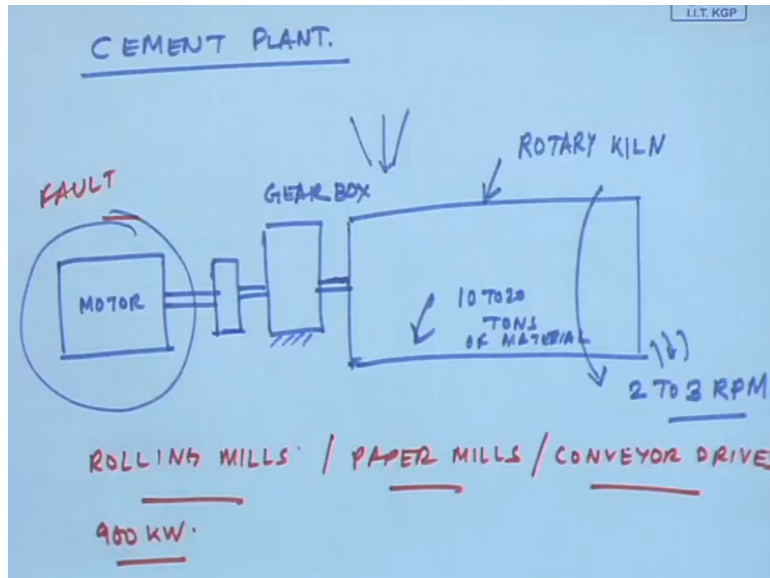
Machinery Fault Diagnosis & Signal Processing

- Turbine Type Generator (660 MW)
- Hydro-type generator (313 MW)
- Large Induction Motor (8 MW)
- Large Synchronous Motor (9MW)
- AC Commutator Motors (900 kW)
- DC Machines- Traction Generators and Motors

So well if I has to classify electrical machines there could be many different types of electrical machines by machines. I essentially mean a motor or a generator particularly if you go to the steam power plants or the hydro power plants. We will see large generators and typical capacity large types of generators would be around 660 megawatts. Hydro generators will be about three hundred thirty mega watts and so on.

And of course if you go to the plants large rolling wheels extra will be having large induction motor or synchronous motor of the around 10 megawatts and power. Then we have the AC commutator motor around nine hundred kilo watt and invariably in many plants in steel plants, paper mills, cement plants. You will see these kinds of motors are used and this is the single most prime over in their plant. For example just to begin with if I give you an example of a cement plant.

(Refer Slide Time: 03:03)



Essentially we have an motor through a coupling with draw you say gear box and then actually to this gear there is actually a large kiln. I have to draw in series, but actually it is next to the gear box. This is the rotary kiln which rotates approximately about 2 to 3 RPM. But it could be carrying loads of several tons, maybe ten to twenty tons of material the idea is an cement plan. All the mix is added there is a fitting device here and then it is turn with a hard grinding media and then you will have the powder cement coming out.

But our focus is we know, how to find out the faults cracks in the kiln which is the common type of failures in kiln failures in the gear boxes are the couplings are known to us through (()) (4:38). We can do that but my focus here is on what happens if this motor is at fault. How do you find out fault condition in the motor because if the motor shuts down the plant is shut isn't it. So let us see and if this is the case of a cement plant, same is to rolling mills, paper mills, conveyor drives.

The paring unit are this motors, so motors are usually an AC commutator motor. Typically 900 kilo watts in power because there are other motors we will be using and they all are almost designed to run at constant speed. This gear box because from an RPM of 1440 RPM, you are finally rotating the kiln 2 to 3 RPM. So you can imagine the amount of speed reduction which is being brought about the gear box.

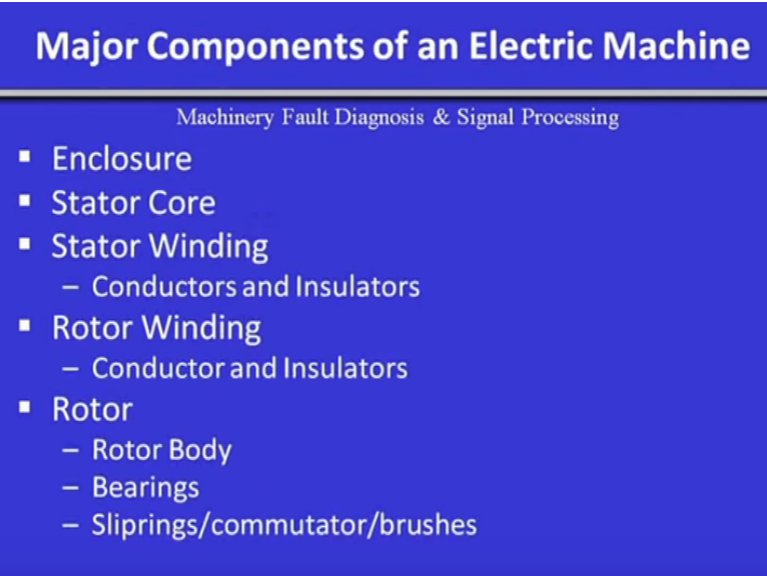
This is a heavy gear box, multistage gear box and so on. Now realizing the importance of fault detection in motors, we will see what are the possible different types of fault which can occur in

an electrical motor before I use in. We have the DC machines particularly in you railway locomotives. The refraction motors generators and when you go to the (()) (6:22) gas turbines are used to power the propulsion unit.

Also these gases turbines are also used to drive a generator which is used to power provide electrical supply to the ship. In fact there are ships where in we have a gas turbine driving a generator. This generator drive again a motor which is going to drive a proper shaft. All the electrical drive as systems are there of course, you know there are advantages and disadvantages.

Because once you have this electrical drive, this systems and a ship they say that you know the load at one end is pretty strong, a pretty heavy load. So there can be just enough stability and instability in a ship and so.

(Refer Slide Time: 07:11)



Major Components of an Electric Machine

Machinery Fault Diagnosis & Signal Processing

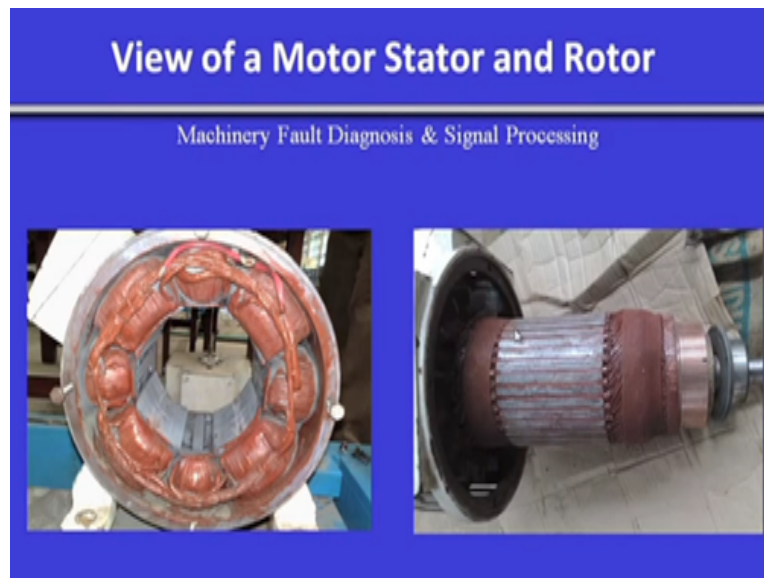
- Enclosure
- Stator Core
- Stator Winding
 - Conductors and Insulators
- Rotor Winding
 - Conductor and Insulators
- Rotor
 - Rotor Body
 - Bearings
 - Sliprings/commutator/brushes

What are the major components of an electrical machine? Here I am usually referring to a motor I am not talking about an electrical transformer. Now we will discuss about the transformer later in this class. So essentially an electrical machine has a stator which actually gives this kinetic field to give this magnetic field. We need to have the copper conductors of the windings.

They have to be insulated and then of course we have the rotors along with its conductors and rotor bodies. Actually a long shaft in which the conductors are placed rotors has to be supported on the bearings and these bearings are actually put in the enclosure and then the motor seal it will to give supply to the rotor. We have either the brushes, slipring, commutator. So failure in any

of these will eventually lead to the failure of the motor. Even the failure of a motor bearing is also very important to consider.

(Refer Slide Time: 08:20)



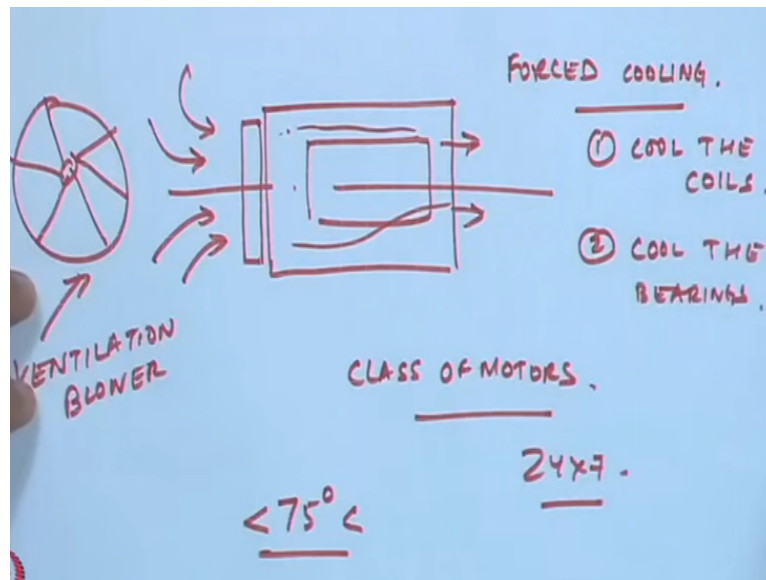
With this let me just give you victorial view of a motor. We just opened up in the lab so that you all are able to see. This is how an electrical motor looks in the inside, this is the frame of the motor. This is this stator and once we give electrical supply there is an magnetic field in this. Because of this magnetic field there will be flux induced in the rotor is nothing. But again series of conductors put together.

This each one is a conductor and these are all very soft material, then it have good magnetic properties. This is the shaft rotor which actually six of the motor and you can see one bearing at this. There is another bearing at another end and this is how it is placed. So this rotor diameter here about 6 inches. But let me tell you there could be motor about 6 meters, you know you could move a truck inside it, I am not kidding.

But motors can be that big but also motor can be very small and that depends on power and so on. Obviously big motors require lot of other functions in the sense. Because of the eddy current losses that will be lot of heat generation. You would have seen when a motor runs it becomes hot and if the temperature heat is not dissipated, the temperature is going to rise. Once the temperature raises it many have many effects.

It may heat up the coils, degrade the insulation, and damage the bearing. Because the lubrication in the bearing will get baked and once this lubrication gets baked there will be hard particles. Hard particles they are going to scrape the inner surface and the bearings will become rough. So when you have fault developing in an electrical motor, you will see that in large electrical motors they constantly monitor the temperature of the driven and non driven bearing.

(Refer Slide Time: 10:33)

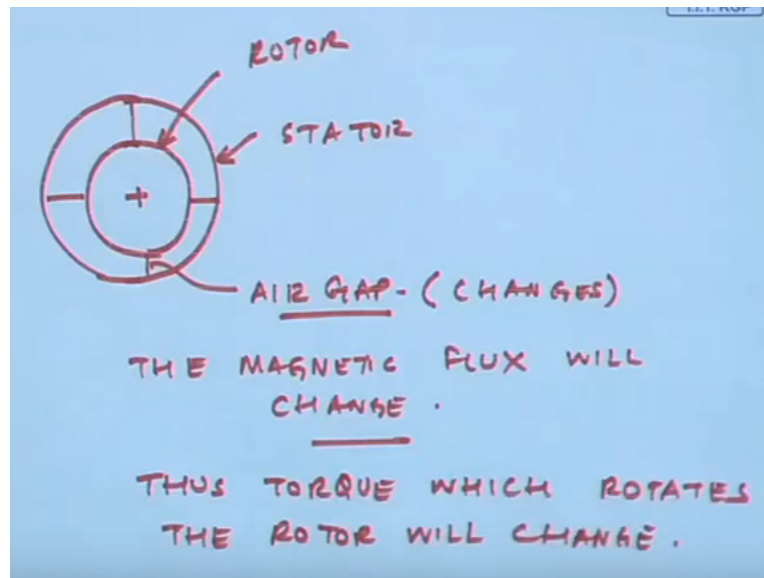


Because we would have seen at the end of the motors particularly there are so this is the rotor here at the end. There is a ventilation blower, so basically it is going to suck in air and then pass through this and then the motor is going to come out. So forced cooling is done to cool the coils, by coils I mean the rotor coils and the stator coils. Cool the bearings, there are class of motors which specify. There are motors which continuously round the clock 24 / 7 continuously in a plant and only take breaks on maintenance.

Other than that they run continuously. There are motors which run on short spans. So you can imagine if heat is not dissipated, I mean this temperature is going to build up. Typically the bearings are maintained to be in the safe side. They should be around 75 degree Celsius and in fact in some special motors there are alarms which lets you known that the bearing temperature is increasing either heat the motor shuts down or we have to have extra cooling unit to cool the motors.

So this could be a serious problem because once the motor heats up, there may be unequal differential expansion. One conductor for some reason may expand than the other and this differential expansion will lead to misalignment having no concern concentricity between the rotor and the stator. One will deform more than the other.

(Refer Slide Time: 12:53)



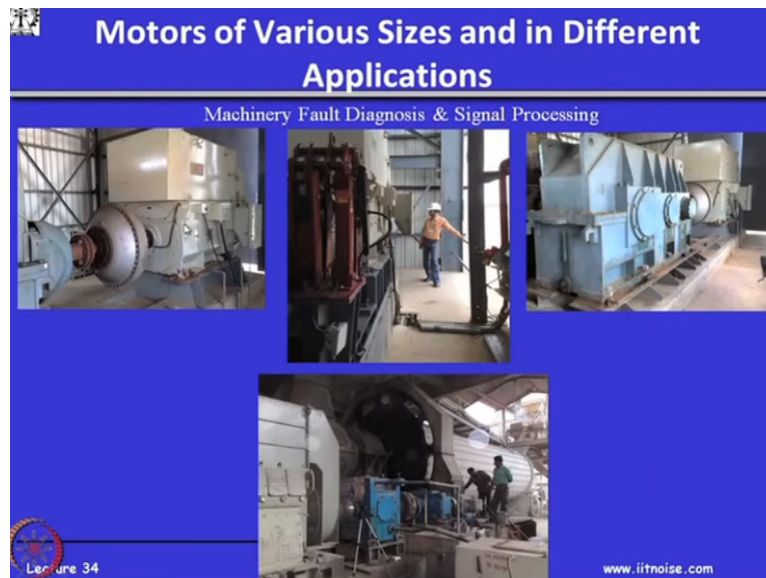
So for example of thermal expansion or some other reason there is a change in the air gap. Essentially this is the stator, rotor, air gap. If your air gap changes the magnetic flux will change and once this magnetic flux change the torque which is responsible for rotating the rotor is going to change. So many things would happen because of this for some reason, I have a different air gap flux is going to change, torque is going to change.

If torque changes I will be having a pulse rating speed I mean this was supposed to have an uniform speed like this. But it may so happen that suddenly there maybe this spacing is going to change. So this may become like this and again pull up. So speed change may occur and torque changes means your forcing function is no longer steady.

Forcing function is changing the dynamics is going to change and over the period if this goes unnoticed, this is going to be a fatigue load on the machine. So you see just one component or aspect it is left unchanged or unnoticed. It is going to have dominant effect and that is why we have failures in machines. Anytime we see a defect initiating you take remedial methods to

remove it mitigate it. Otherwise if it goes unchanged it is going to affect the downstream operation and that is true for anything. As I was telling you this is a motor.

(Refer Slide Time: 15:34)



This is an electrical motor about a 900 kilowatt of capacity and you see this unit here is nothing but the blowers where in the air comes in to cool such a big motor. This is driving a gearbox actually and you will see this gear coupling. In a gear coupling as I was telling you earlier the coupling along such for the thermal expansion, motor is fixed.

In the gear is fixed there are bearings on which these rotors because of thermal expansion can slide and if they do not slide, they are fixed and they are going to bend. The bend again you know same problem air gaps are going to change. Then we will have pulse rate in forces, so this is why a large machine we have gear coupling. Basically there are two gears, one over the other and they will just slide.

Little sliding is there so that takes care of the thermal expansion and this usually again usual drive a conveyor system. You can see the dimension, there is a technicians standing here and you can see how big this motor is compared to the person. This is another view of this motor which is driving a multistage gearbox. In fact you can see three shafts here 1, 2, 3 and you can see the directions 90 degree arrangement here.

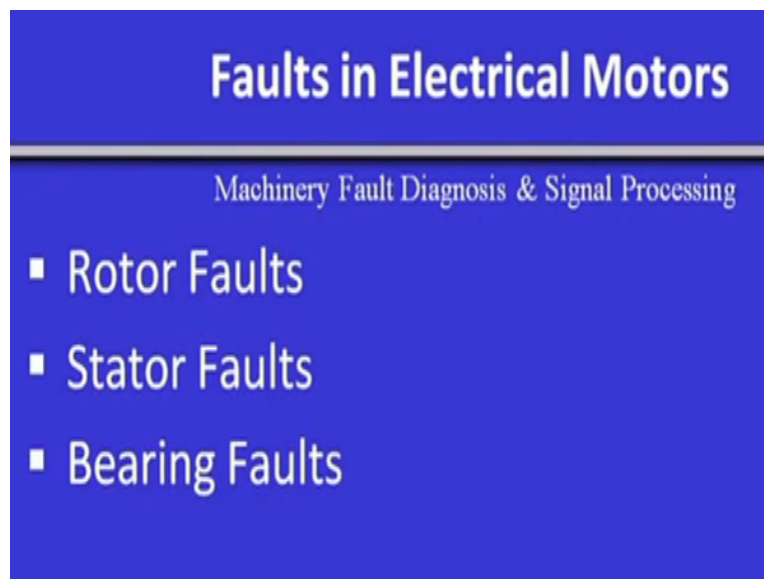
So they will give arrangement power, is coming in this direction and power is going out in this direction and these machines are maintained. The alignment has to be perfect otherwise if there

is alignment again the Rotor at one end of the motor is going to have an excessive force and bearing at one end get damaged.

This is the view of one of the motor which is having a massive reduction gearbox and this actually that rotary kiln of that cement plant I was talking about and you can see the dimension compared to this person and this motor charge 1440 RPM. But this kiln is only rotating at 2 to 3 RPM. So there is a heavy reduction gearbox as well here, so critical to the plant is this gearbox. This motors with the Motors die a plant does not operate.

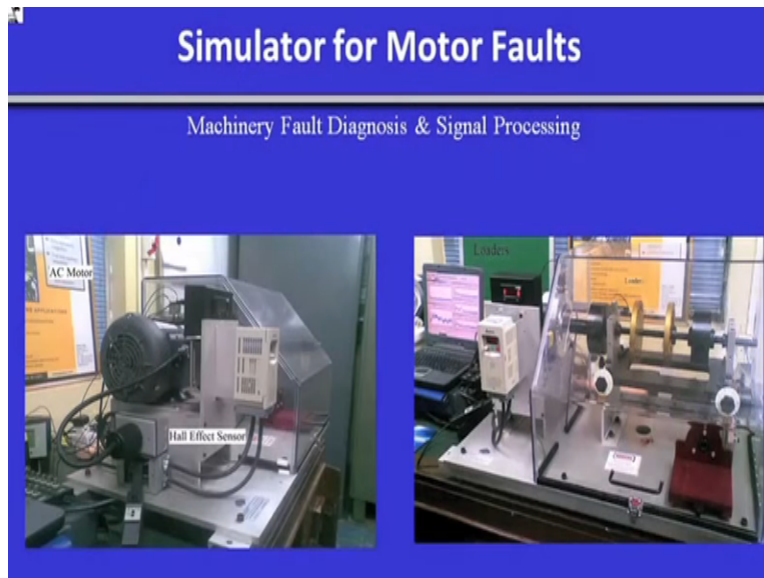
So you can imagine ships will not get unloaded, cement will not produce steel, may not work. So you can have serious effect to everybody. I mean you can imagine life without electrical Motors. Nowadays it is just not possible I mean even in small watches to even rocket engines, we have to rely on electrical Motors and that is very important. I would say mechanical component, electrical component, any component you call it is a very important engineering component which we have to know and which we have to care for.

(Refer Slide Time: 18:34)



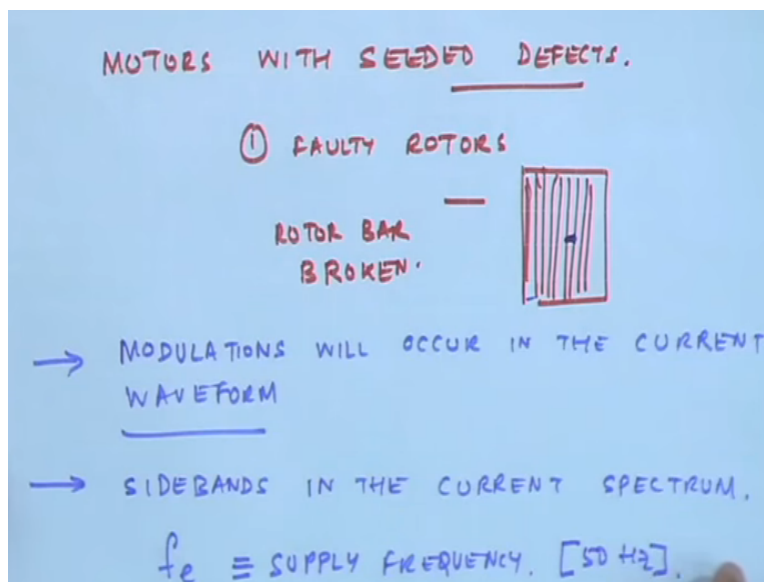
So with this kind of background about electrical motors. As you know, now this rotors can have faults stators can have faults and the bearings of the Motors. Obviously they can have faults and you know how to find out the fault in bearings.

(Refer Slide Time: 18:56)



So what we did in this laboratory, we have an motor which is driving mechanically. This rotor which is supported on a bearings and we are now concerned with this Motors.

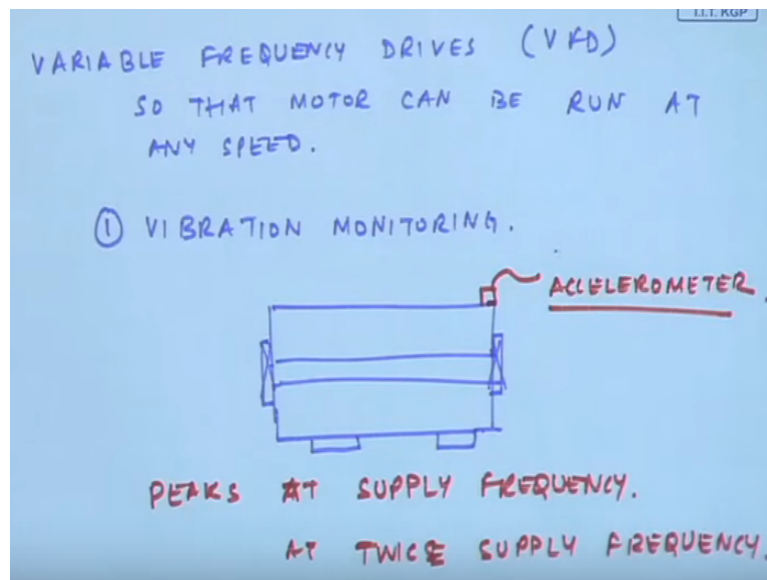
(Refer Slide Time: 19:24)



Seeded defects I mean there could be faulty rotors. Typically faulty rotors mean you have seen those rotor conductors like this slots. So rotor bar broken is a common mechanical fault. What happen if one of the rotor bars is broken? The current which is supposed to flow through this conductor is not going. But to balance the load, the current in other conductors are going to increase momentarily. So this will give rise to an unbalanced torque.

Because of this torque there will be modulations will occur in the current waveform and from your study of signal crossing modulations in the time domain will give side bands in the current spectrum. So once we see sidebands around this supplied frequency typically supply frequencies, F E by supply frequency. I mean supply frequency to the electrical motor and typically in our country it is 50 hertz but now with this many of the motors they use.

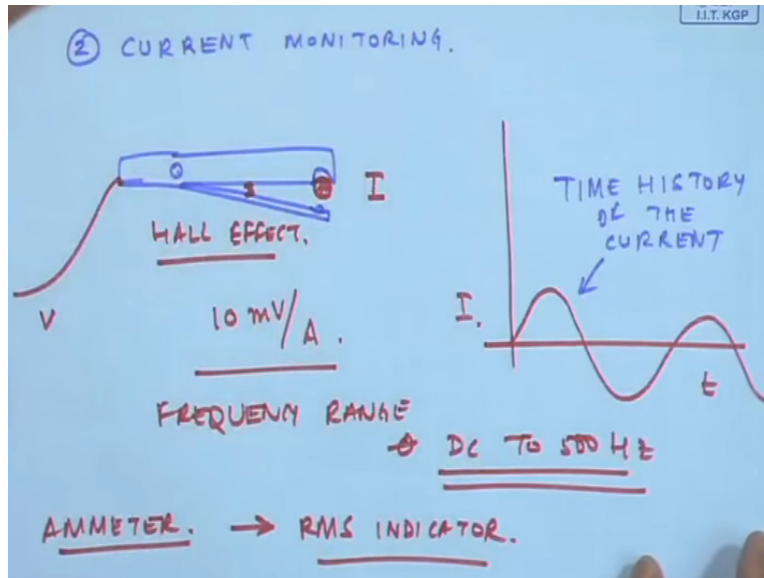
(Refer Slide Time: 21:45)



Nowadays variable frequency drives or what is known as VFD. So that motor can be run at any speed by the way for a supplied frequency. In our country is 50 hertz but in USA it is 60 hertz and how do you find out the fault. We can still do our good old vibration monitoring on the Motors. I mean nobody has asked us not to do, we can do vibration monitoring put an accelerometer on the motor. I can put accelerometer here, to do vibration monitoring and here what will happen.

You will see sometime I will see peaks at supply frequency and also at twice supply. You will see the reason why you were getting this twice supply frequency electron. In this class we can do vibration monitoring. But in this class since you already know what vibration monitoring is and all you do is put vibration sensor close to the bearings of the motor record.

(Refer Slide Time: 24:04)



The time history and then do VFD but we can also very easily monitor through what you know as the current monitoring and in this experiment here, to measure the current which we are using actually an hall effect sensory evaluation. You can see a sensor is like a clamp on conductor this will be something like a spring loaded thing and then all you have to do is the conductor. Actually this is spring loaded the conductor will actually come here and then you will get voltage. So if I am measuring a current I will get a voltage here because of the Hall Effect.

I will get voltage which is portioned to the current and with time I can be measuring the current. Usually hall effect sensors have sensitivity of maybe 10 mill volt per ampere. The reason we are using hall effect sensor because they have high frequency range all the way from maybe 0 or DC to about 500 hertz I can measure with search hall effect sensor. Traditionally we measure current ammeters but ammeters are very poor frequency response.

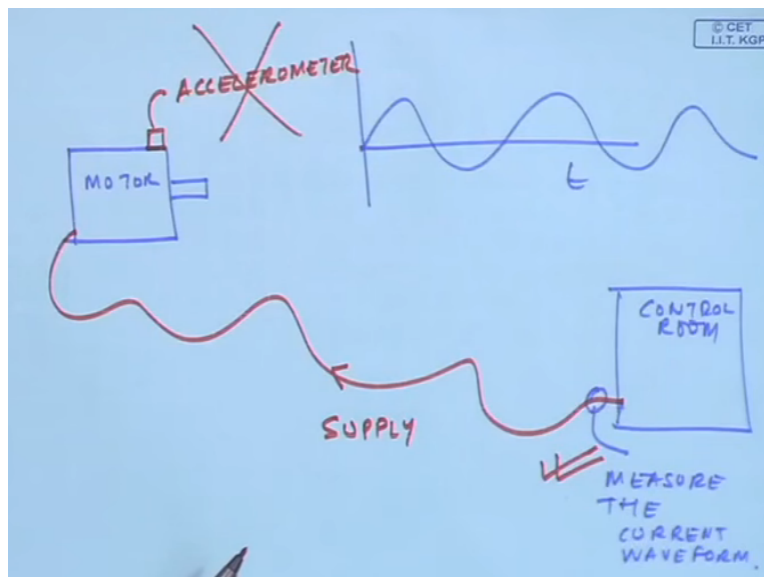
The only measure around the fifty hertz supply frequency and all we get is an RMS indicator which only gives us the RMS value of the current. But hall effect sensor I get the time history, I can record the time, you measure and record time history of the current. Once I get the time history of this current the entire waveform is available with me.

So with the signal analysis system I can do the current spectrum analysis and then try to know whether sidebands are there, weather sidebands are not there and so on. So this becomes a very convenient way to measure the condition of the electrical motor, rather than doing a vibration

monitoring. If I do the vibration monitoring I am not sure sometimes I will get sidebands around supply frequency.

That may not happen, I may see only peaks at supply frequency and twice supply frequency. But that is why the measuring and monitoring current become a very powerful and convenient technique of monitoring the motor faults. Imagine you are sitting somewhere in the control room, where in electrical motor is maybe miles away. All you can do is lay a current conductor from your motor. So you need not go to the motor. I will tell you why and how suppose we have a motor.

(Refer Slide Time: 27:33)



And you are sitting somewhere in a control room, obviously to drive a motor it requires supply cable is going from here. I just have drawn one conductor, so very easily you can measure the current waveform. So now you can imagine the power of motor current and measurement of motor current. Remotely motors is also underground motor, over the ground motor is miles away from you.

But as soon as you have access to the supply lead going to the motor, you just measure the current waveform, you will record the current waveform and then does your single crossing find out the condition of the motor. This is why motor current signature analysis has become very powerful and we are not even going close to the motor. If I was to measure the vibration I have to go at least close to the motor to mount an accelerometer and that is not required.

Now if I am through this is not so in this simulator, which we have used in the laboratory. Of course I have an hall effect sensor and you can see this hall effect sensor connected to signal analyzer where we are analyzing the current which has been measured by this and you can see the time history of the current the spectrum.

(Refer Slide Time: 29:33)

Source of Twice line frequency in Electric Motors

Machinery Fault Diagnosis & Signal Processing

$$W_e(t) = i(t)e(t) = EI \cos 2\pi ft \cos(2\pi ft - \phi)$$

$$= (EI/2) \cos \phi + (EI/2) \cos[2(2\pi f)t - \phi]$$

Produces
Steady
torque

Produces Unsteady
Torque at twice line frequency

I was just mentioning that what is this source of this twice line frequency in electrical Motors. You will see if you multiply this two waveforms power is nothing but current times EMF if I multiply this $E I \cos \pi f T$ and $\cos \pi f T - \text{difference}$ occur phase between current and the EMF. I will get expression one is a cosine π plus cosine two ω where ω is $2 \pi f$.

So one produces this steady torque which is responsible for the motor and there is also unsteady torque at twice supply line frequency, that is why when you do the vibration measurements or the current measurements. You may sometimes land up with strong two times the supply frequency peaks which comes out many a times people ask me this question.

Why am I in a 50 hertz motor? Why am I getting a 100 Hertz peak and this is the reason. This is the mathematical reason behind it just nothing but multiplication of two techno metric function gives two Ω torque.

(Refer Slide Time: 30:51)

Broken Rotor Bar Frequency

Machinery Fault Diagnosis & Signal Processing

$$f_{brb} = f_s \left[k \left(\frac{1-s}{p} \right) \pm s \right]$$

(Refer Slide Time: 31:03)

CURRENT ANALYSIS.

The diagram shows the equation $f_{brb} = f_s \left[k \left(\frac{1-s}{p} \right) \pm s \right]$ with several handwritten annotations in red ink. An arrow points from the text 'Integer' to the variable k . Another arrow points from the text 'slip' to the variable s in the numerator of the fraction. A third arrow points from the text 'pole pair in the motor.' to the variable p in the denominator. A fourth arrow points from the text 'broken rotor bar' to the variable f_{brb} . A fifth arrow points from the text 'Supply Frequency' to the variable f_s . In the top right corner, there is a small logo that reads '© CET I.I.T. KGP'.

Now let me go back to how this current analysis can be done to find out the rotor faults. Perhaps this equation is not coming clear, I will just write just down here. This means, if there is a broken rotor bar the frequency in the current spectrum is given by this is the K an integer, S is the slip, P is the pole pair in the motor. So in any AC motor because slip will occur.

Because there is a difference between the spectrum speed and the rotor speed pole pairs are there and this is all functions of the supply frequency. I will get the frequency of the rotor bar given by this expression and they will actually come up as sidebands in the current spectrum and this can be calculated.

(Refer Slide Time: 32:44)

Reasons behind Broken Rotor Bars

Machinery Fault Diagnosis & Signal Processing

- Thermal stresses due to overload and hot spots
- Magnetic stresses created due to electromagnetic forces, unbalanced magnetic pull
- Residual stresses due to manufacturing process
- Dynamic stresses due to centrifugal forces
- Environmental stresses due to contamination and abrasion by chemicals, moisture etc.
- Loose laminations, fatigued parts etc.

Now if rotor bar, why does it break? What are the possible reasons, one is thermal stress due to overload and hot spots. There will be a linear expansion and then there will be hot spots extra. Magnetic stresses created due to electromagnetic forces, unbalanced magnetic pull I just told you because of the air gap is not maintained. There will be pulse rating magnetic field during the manufacturing process all of the bars where not having the same stress relieving.

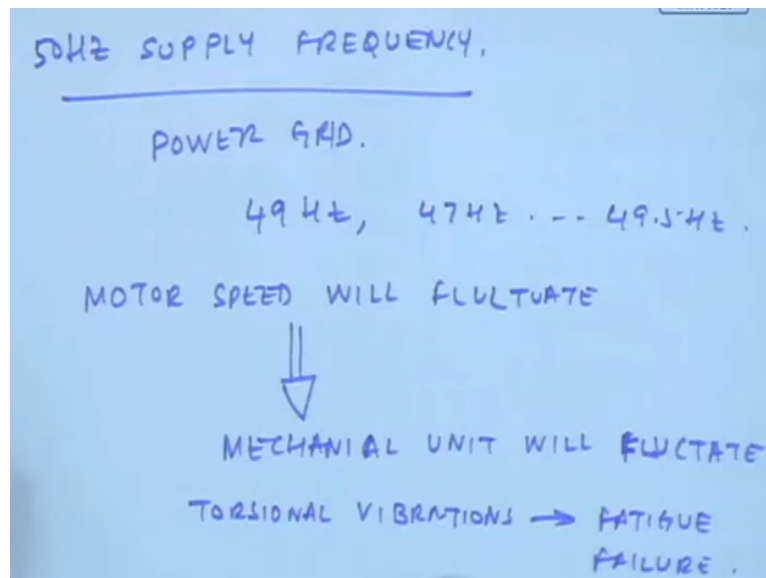
So some could be having a residual stress because I am rotating the centrifugal force and the stress. There could be moisture abrasion by chemicals contamination. That could lead to the wear and tear of the rotor bar. There are so many loose components in the rotor bar. They are actually fixed in the slot. Few of them could be loose and they could be rattling and then they will fatigue.

So a good motor takes care of the issues, are not there in Motors. If you go to the market for the same power, same performance. You will get Motors with varying amount of price. That is one of the reasons. The quality somebody would have taken care of that good uniform winding from air gap, good bearings not loose.

There are enough provisions for cooling extra. So this is why motors, these are the possible reasons why these rotors bars can fail and if this router bar few rotor bar fails. If one goes unnoticed fine if 10 goes unnoticed you will see a lot of time creating such unbalanced torque that it is going to have effect on the operation of the plant. I have seen many a cases even the

supply frequency to the electrical motor create a lot of problem in the plant. I will tell you how and why so for example the plant.

(Refer Slide Time: 34:55)



As I am supposed to get 50 Hertz supply frequency but because of power grid supply, I am getting 49 Hertz, sometimes 47 hertz and so on. And sometimes 49.5 extra. So there is a constant fluctuation of the frequency. So the motor speed is going to fluctuate. So in effect if the motor driving a mechanical in it is also going to fluctuate. So this is going to give rise to fluctuating torque.

There will be lot of torsional vibrations which will lead to fatigue failure. I have seen many appliances where gearboxes rotate a torsion bar or actually long rigid bars with good amount of rigidity. They have sheared at the 45 degree axis because torsional shear stress as well maximum and then it fails because of what are the call it was the fluctuating speed of the motor. So there are of course you know I mean modern machines.

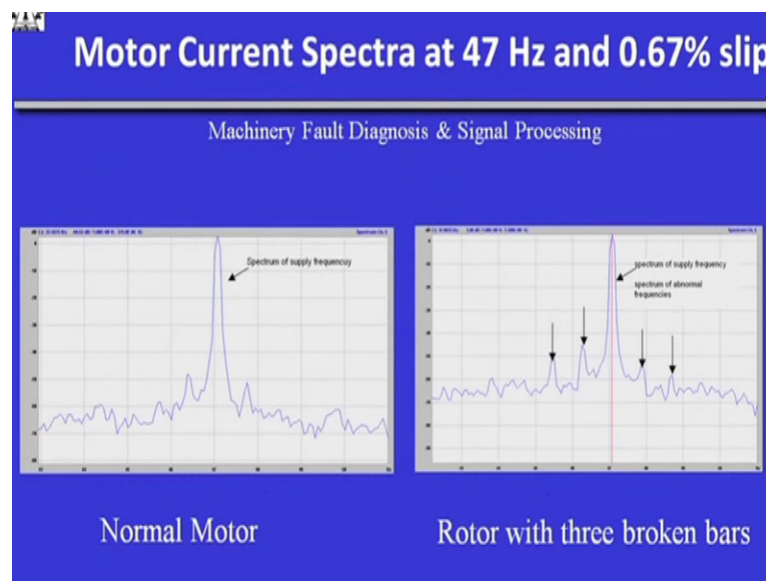
There are many safeguards to prevent that the system itself will trip. You have seen how the grid failure had a down effect. One by one the grids fail the powers, you see you do not take up the load speed and frequency is again going to increase. So there is always in the bar generation place. There is always maintain balance the load the production and rate. So they have to be monitor if you have ever been to power plant.

You will see they constantly monitor the supply frequency of the power generation frequency of 50 Hertz. If I put in more steam there has to be governors to limit it and to run at 50 hertz. Otherwise if I do not govern it speed will increase Power Will supply frequency is going to increase. We all take it for granted, but if I have a if you know a generator is suppose run at the same constant speed.

So if I given more fuel or more steam whatever to the steam generator is going to increase you would have noticed that in ice engines. If fuel is more and throttle if I press the throttle more the car moves faster. The engine going faster, but imagine if you generator is going to move faster, the supply frequency is going to change. So these are things which we cannot take it for granted. I have been to many plants where they say that mission has failed.

Because of the bearing failed or gearbox failed, but we have founded the faults was actually the supply frequency which was been changing and under supply power plant power generating unit. I actually at fault so good power supply to the plant is very important.

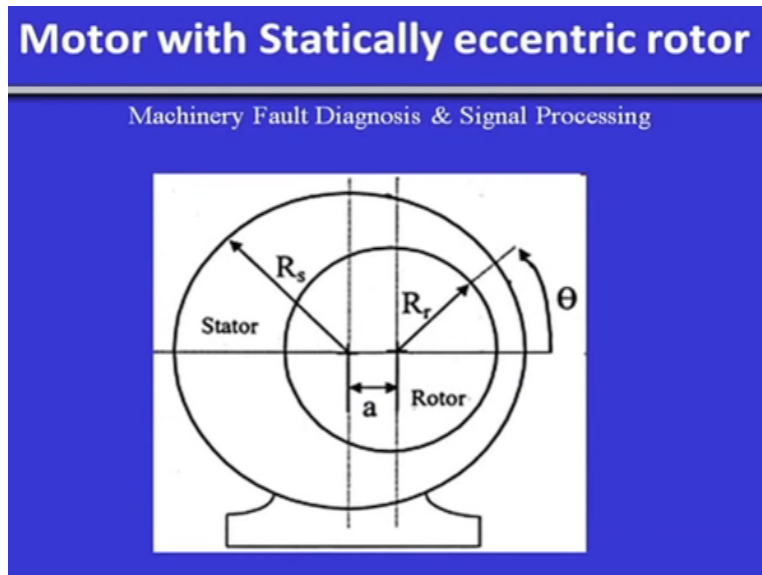
(Refer Slide Time: 38:21)



In this example, here the laboratory what we did is we ramp this motor through the VFD drive and not at the 50 hertz power supply. But at 47 hertz in a very well frequency drive with .67% slip and if you see the normal motor there are hardly in a side bands. These are the sidebands which are showing up at 47 Hertz.

And once we have three broken bars. We can see these are the values of the key. This side bands will increase and then you can see that in decibels that the peaks are going to increase which are the defines the rotor bar has failed.

(Refer Slide Time: 39:03)



There could be cases where the motors could have an static eccentricity. This is the stator, this has been exaggerated here and they have an exsensitivity.

(Refer Slide Time: 39:18)

Reasons behind static eccentricity

Machinery Fault Diagnosis & Signal Processing

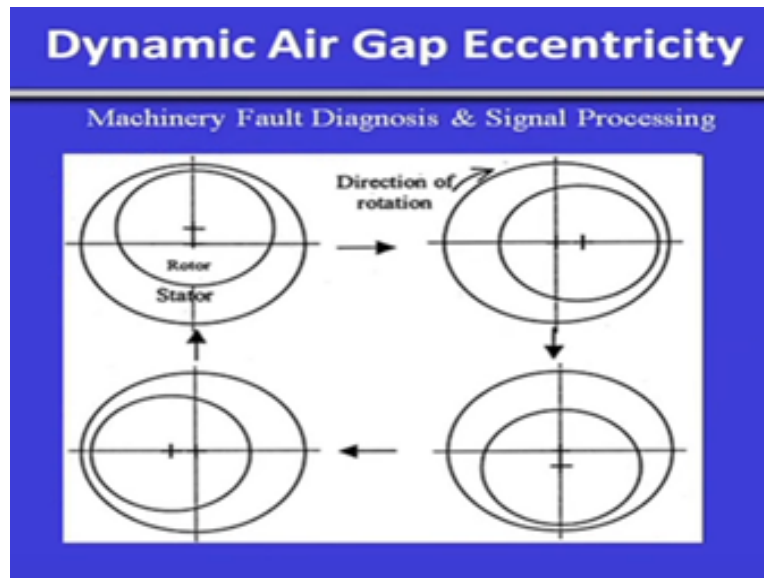
- Ovality of the stator core
- Out of tolerance spigots in the end frames that house the bearings
- Incorrect positioning of the rotor or the stator at the commissioning stage
- Incorrect installation

What are the possible result reasons behind the static eccentricity? One is the stator core is not a perfect circle. But oval out of tolerances at the end frames that house the bearings. So bearings themselves are not aligned incorrect positioning of the stator at the commissioning stage. Many

times the rotor are so heavy that they have to be put at the side. They have to be installed and there could be an incorrect installation, one foot is at higher ground.

Then the other and there is a angular deviation. So all this lead to the static eccentricity between the Rotor and the stator and because of this eccentricity. There will be air gap variation and again we will see frequencies coming up in the current spectrum because of static eccentricity.

(Refer Slide Time: 40:11)



Similarly when it is a rotating I will have an dynamic air gap eccentricity. The eccentricity is moving with time you can see this entire thing is moving. This could be because of the shaft is bend wobbling.

(Refer Slide Time: 40:30)

Reasons behind dynamic eccentricity

Machinery Fault Diagnosis & Signal Processing

- Bent rotor shaft
- Bearing wear
- Misalignment
- Mechanical Resonance at Critical Speed

So one is the bent rotor shaft other is the bearing wear there could be misalignment. There could be mechanical resonance at critical speed. The good motor designer would have insured the operating speed is not at its critical speed or much away from critical speed. Now once we have these kinds of defects and the electrical Motors. They all reflect in the current spectrum, so looking at the frequency at the current spectra.

(Refer Slide Time: 41:05)

Rotor Eccentricity Frequency

Machinery Fault Diagnosis & Signal Processing

$$fe = f_s \left[(kR \pm n_d) \frac{(1-s)}{p} \pm v \right]$$

We can find out the faults there are the equations also here of the supply frequency because of the rotor eccentricity.

(Refer Slide Time: 41:12)

Dominant frequency in the current spectrum due to eccentricity $f_e = f_s \left[(kR \pm h_d) \frac{(1-s)}{p} \pm v \right]$

Supply frequency f_s NO. OF ROTORS kR Integer. h_d Slip s pole pair p Integers v

dynamic eccentricity ≈ 0.25

Again this is not visible I will write it here, many of this is the number of rotors and this is an integer. These are for all cause depending on the motor. This typical value plus minus ND for eccentricity for dynamic eccentricity. This is about point two, so these are again some integers. So researchers have found this formula by which we will see the frequent dominant frequency in the current spectrum, due to eccentricity.

We can see this in the spectrum I will give you another and this could be because of static eccentricity because of dynamic eccentricity.

(Refer Slide Time: 43:20)

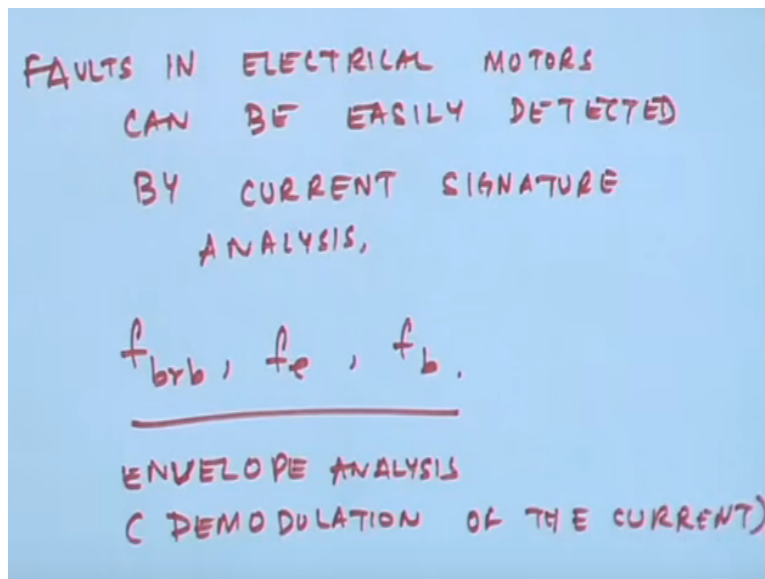
MOTOR BEARING FAULTS.

$f_b = f_e \pm n f_m$

BEARING FAULT FREQUENCIES IN THE CURRENT SPECTRUM. f_b SUPPLY FREQUENCY f_e Integer. n bearing frequencies (IR, OR, BSF). f_m

Another fault which happens in motor is bearing faults also reflect in the motor current. There will be nothing but applied frequency plus minus some number and these are nothing but the bearing frequencies. If you know the bearing has another defects, outer defects, the balls spin. These equations can come these frequencies can be found out here and these are integer. So in the supply frequency, we will see sidebands about the wavelength frequencies and this will supply frequency.

(Refer Slide Time: 45:02)

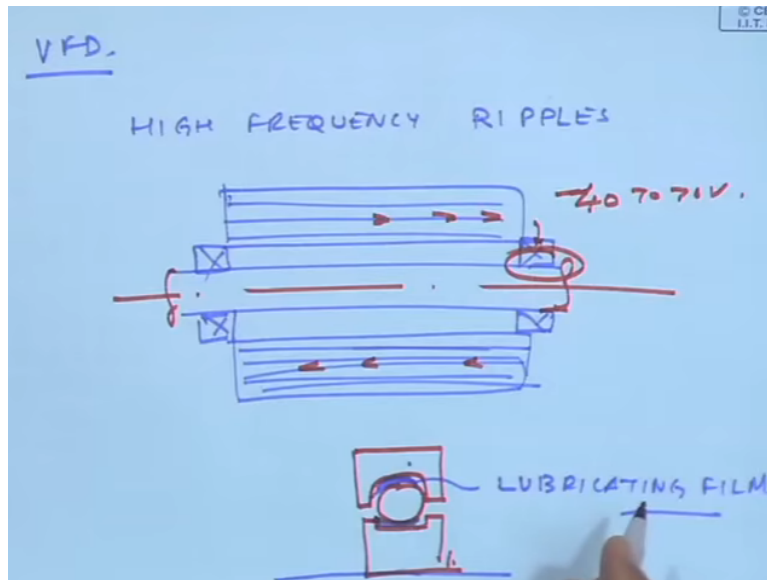


FAULTS IN ELECTRICAL MOTORS
CAN BE EASILY DETECTED
BY CURRENT SIGNATURE
ANALYSIS,
 $f_{brb}, f_e, f_b.$
ENVELOPE ANALYSIS
(DEMODULATION OF THE CURRENT)

So in effect if you do faults in electrical Motors can be easily detected by current signature analysis. All you have to do is you have to look out for this frequency of the rotor bars frequency because of the eccentricity frequency. Because of bearing, so on just in the equation in previous slide on how there can be estimated. So that the current signature unless there will be actually modulated.

So we have to do an envelope analysis which we have discussed earlier or just what is known as the demodulation of the current to find out this and load which defect severity this side bands is they are going to increase in the magnitude. Another defects which occurs in motors, nowadays that we are using VFD drives and electrical motors.

(Refer Slide Time: 46:36)



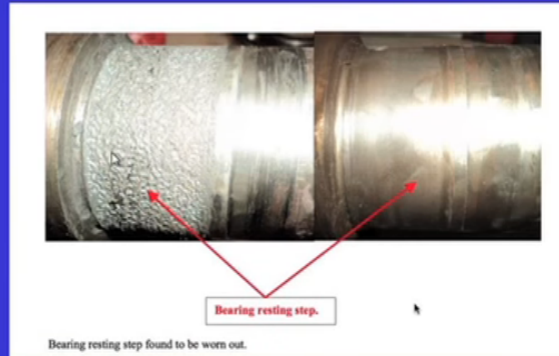
Because of this VFD drive, there are lots of high frequency in the Ripples. I have this motors are the bearing, this rotor here. What happens there will be a current flowing in this conductor and which gives a voltage loop and particularly at the bearing what happen and these are very high frequencies and they could be we having voltages of about you know typically about 40 to 70 volts and they are going in this loop here.

What happens at the bearings you will see there will they will be a dielectric film which is actually an insulator. So each time the voltage increases there is actually a spark across this outer rays which is attached to one end and inner rays which is attached to the shaft and actually the shafts shift here during shifts. So what happens whenever this bearing is shifting? There will be kind of sparking occurring between the bearing and the shaft. This spark actually is responsible for eroding.

(Refer Slide Time: 49:07)

Pitting Marks on Bearing Step of VFD Controlled Motor

Machinery Fault Diagnosis & Signal Processing



The shaft bearing was shifting here. You can see this goes undetected particularly, the variable if it is drive because of the high frequency ripples. They will be sparking on the surface, the shafts become worn out like this and spark shaft become weak. So how do you take care of it is you have to produce an alternate path to this current by grounding.

This by grounding the shaft, so by chance shaft is here you have to ground the shaft grounded. So that the current flows through that two times. There is no discharge taking place, now it is close to people are using VFD drives and they are coming up situations where the bearings are having faults getting marks or soft surface.

(Refer Slide Time: 50:13)

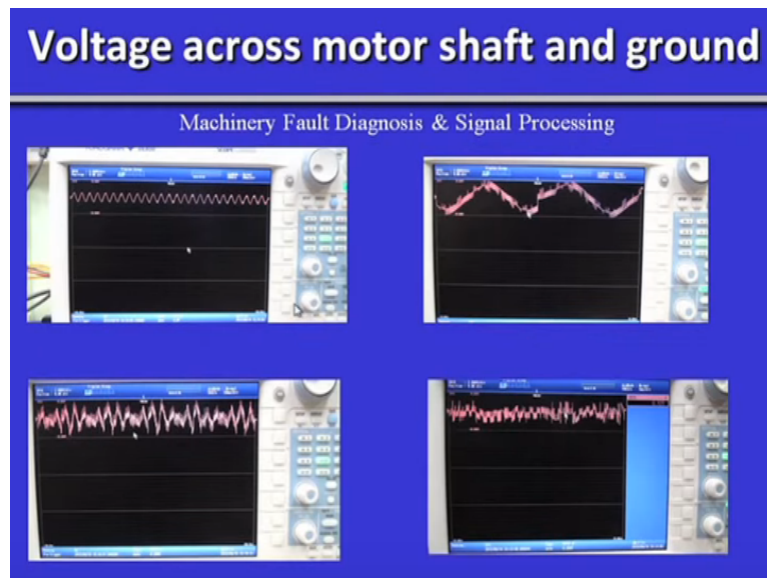
Voltage Measurements in VFD Motor

Machinery Fault Diagnosis & Signal Processing



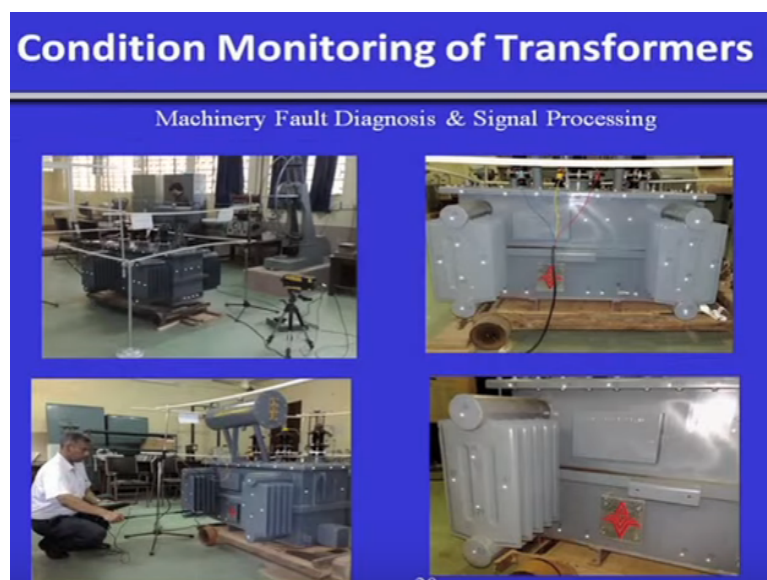
This we did in our lab, we basically measured just the voltage on the shaft. Here of course we are measuring it and then.

(Refer Slide Time: 50:25)



We recorded it voltage across motor shaft. It is a normal case but when we have wave drives. The different frequencies we have seen how that these frequencies are there and then the discharge. They actually damage these PQ frequencies. This our highest forty to seventy volts and then damage the motor shafts. So motor current motor can be faults can be detected through this technique which we discuss mostly through signature analysis though you can also do vibration monitoring of electrical motor.

(Refer Slide Time: 51:10)



Then how do you monitor the condition of Transformers? Basically you would have seen in transformer essentially is nothing but more of coils. This coil is actually kept in a tank full of oil and this oil is actually maintained for a particular height and because of again the eddy current losses. This current generates heat has to be dissipated. That is why these are like since you would have seen in mini Transformers.

There are two bins extra which carry nothing but oil and this is the tank where in oil is there and you would have heard of scenarios where there is a power out range because of the transformer burst. Why did that best happen? Because the Transformer was drive the maintenance crew would not have ensured that the level of the oil which should be there was not there and that is the reason why Transformers bust.

So in our laboratory here what we are trying to trying to measure the vibration of the transformer. There is no secondary discharge here, we are just done the primary exaggeration and this is a very high, 100 megawatt transformer trying to analyze. We are measuring the noise here and here though obviously we cannot go near the Transformer we need to measure the vibration and there is a sound intensity throughout.

But usually the condition monitoring of transformer is done by monitoring the condition of oil. We discuss about oil analysis, so by monitoring the condition of the oil whether it has retained physical property, chemical properties. We can know periodically by taking samples of the transformer oil whether it has got contaminants with moisture whether it is time to change, change oil.

How this transformers are taken care again for an electrical Switch Gears when there is contact disk and non contact lot of heat generation and we will discuss in the class on thermograph. How through thermal analysis are temperature monitoring. We can also find out faults in electrical systems. Thank you.